

Standard Experiment No. 03

OSBORNE REYNOLDS EXPERIMENT: LAMINAR AND TURBULENT FLOW

A Laboratory Report
Presented to Engr. Miller Cutora
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In Partial Fulfillment of
The Requirements for the Subject
Hydraulics Laboratory
(LBYCV2D)

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August 7, 2020

CRITERIA	RATING
1) Problem Statement. (10%)	
2) Theory and Application. (10%)	
3) Data Computation and Analysis. (40%)	
4) Quality of Written Report. (40%)	
TOTAL:	

I. OBJECTIVES

- To show the manifestations of turbulent and laminar flows
- To determine the Reynold's number as a criterion for classifying flows
- Complete the table and the required information in the data sheet. Explain your findings. At which critical Reynolds Numbers do the laminar, transitional, and turbulent flow manifest itself?
- Draw the form of the streak lines that you might observe in all trials. On the column for remarks, give a description of the flow like – straight, wavy, diffused, increasing wave amplitude, etc.

II. THEORETICAL BACKGROUND

At about the 19th century, Osborne Reynolds developed an apparatus by which he demonstrated that there were two regimes (mode) of flow in a pipe. The apparatus allowed the injection of a dye into a pipe through which water is flowing at specified rates. The dye served as a tracer for the movement of the water. In the first mode, the water particles (following the streak lines produced by the dye) follow along straight lines parallel to the axis of the pipe, but in the second mode, water particles seem to follow a random path throughout the pipe (diffused dye), only the average motion being along the axis of the pipe. The first mode is called laminar flow and the second mode, turbulent.

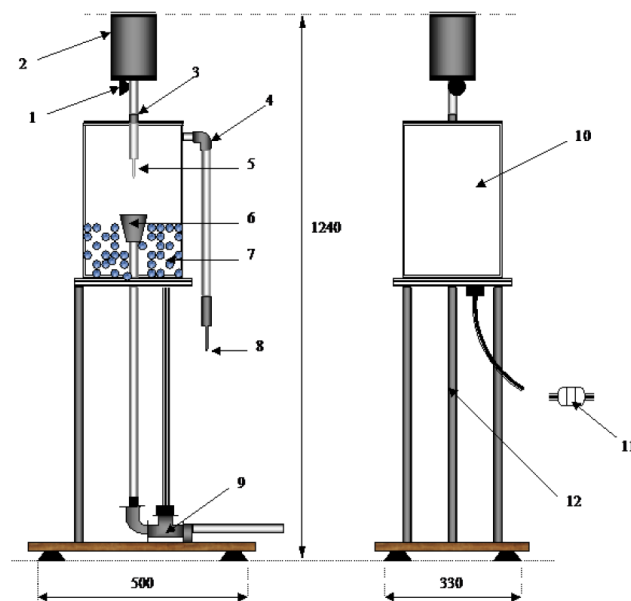


Figure 1: Osborne Reynolds Apparatus

Legend for the Osborne Reynolds apparatus:

1. Dye Control
2. Dye Container
3. Adjustment Screw
4. Overflow Pipe
5. Hypodermic Tube
6. Bell Mouth Entry
7. Glass Marble
8. Flexible Outlet Pipe
9. Flow Control Valve
10. Head Tank
11. Inlet Pipe
12. Flow Visualization

The value for the flow rate is found using the formula:

$$Q = \frac{V}{t} \quad [\text{Eq. 1}]$$

Where:

- Q = flow rate
- V = volume tested
- t = time for the test volume to flow out completely

The value for the velocity (v) is found using the formula:

$$A = \pi \left(\frac{D}{2} \right)^2 \quad [\text{Eq. 2}]$$

$$v = \frac{Q}{A} \quad [\text{Eq. 3}]$$

Where:

- A = cross-sectional area where the pipe flowed
- D = diameter of the pipe
- Q = flow rate
- v = velocity in the pipe

The Reynold's number was computed using the formula:

$$Re = \frac{vD}{\nu} \quad [\text{Eq. 4}]$$

Where:

- v = velocity in the pipe
- D = diameter of the pipe
- ν = kinematic viscosity
- Re = Reynold's number

The theory is that laminar flow occurs at the Reynold's number of less than 2000, turbulent flow occurs at the Reynold's number of above 4000, and transitional flow would occur at Reynold's number of 2000-4000. The characterization predicted for each of the flow is straight, diffused, and wavy, respectively.

The values of ν were derived as follows:

$$\nu = \frac{\eta}{\rho} \quad [\text{Eq. 5}]$$

Where:

- η = dynamic viscosity
- ρ = density of water
- ν = kinematic viscosity

The values of ρ were derived as follows:

$$\rho = 1.00034038 - (7.77 \times 10^{-6})T_{\circ C} - (4.95 \times 10^{-6})T_{\circ C}^2 \quad [\text{Eq. 6}]$$

Where:

- ρ = density of water
- $T_{\circ C}$ = Temperature in $^{\circ}C$

The values for dynamic viscosity were derived as follows:

$$\eta = 10^{\frac{247.8K}{T_K - 140K}} (2.414 \times 10^{-5} Pa \cdot s) \quad [\text{Eq. 7}]$$

Where:

- T_K = temperature in Kelvin (K)
- η = dynamic viscosity in $Pa \cdot s$
- Note that K in the equation stands for the unit of Kelvin.

For the alternative values of dynamic viscosity, the following formula is used:

$$\eta = A e^{\left(\frac{B}{T_K} + C T_K + D T_K^2\right)} \quad [\text{Eq. 8}]$$

Where:

- T_K = temperature in Kelvin (K)
- η = dynamic viscosity in $Pa \cdot s$
- A, B, C , and D are values found on table 6.

III. DATA PRESENTATION

Graphs, tables, and figures containing the important data and results should be labelled properly.

Table 1: Value of Diameter used

Name	Symbol	Value	unit
Diameter	D	10.37	mm

Table 2: Input values

Trial No.	Volume (liters)	Time (s)	Temperature (°C)
1	1.03	441.44	25.9
2	0.99	146.37	26.3
3	1.08	58.15	25.7
4	0.97	59.84	26.8
5	1.07	36.33	25.7
6	0.97	211.44	26.7
7	1.07	26.48	25.8
8	0.98	26.28	26.7
9	1.09	77.05	25.3
10	0.93	104.04	26.9

Table 3: Other calculations done

Trial No.	Temperature (°C)	Density (g/cc)	Temperature (K)	Dynamic Viscosity (Pa*s)	Density (kg/m ³)	Kinematic Viscosity (m ² /s)
1	25.9	0.996819	299.05	0.000872445	996.8186	8.75229E-07
2	26.3	0.996712	299.45	0.000864628	996.7122	8.6748E-07
3	25.7	0.996871	298.85	0.000876394	996.8713	8.79145E-07
4	26.8	0.996577	299.95	0.00085501	996.5769	8.57947E-07
5	25.7	0.996871	298.85	0.000876394	996.8713	8.79145E-07
6	26.7	0.996604	299.85	0.000856921	996.6041	8.59841E-07
7	25.8	0.996845	298.95	0.000874416	996.845	8.77183E-07
8	26.7	0.996604	299.85	0.000856921	996.6041	8.59841E-07
9	25.3	0.996975	298.45	0.000884377	996.9754	8.8706E-07
10	26.9	0.996549	300.05	0.000853107	996.5495	8.56061E-07

Table 4: Data Sheet

Flowrate (m ³ /s)	Velocity (m/s)	Reynold's Number	Type of Flow	Drawing	Remarks
2.33E-06	0.027626	327.3219685	Laminar		straight
6.76E-06	0.080082	957.3148253	Laminar		straight
1.86E-05	0.219901	2593.850744	Transitional		wavy
1.62E-05	0.191926	2319.80194	Transitional		wavy
2.95E-05	0.348715	4113.289961	Turbulent		diffused
4.59E-06	0.054317	655.0855824	Laminar		straight
4.04E-05	0.47843	5655.965021	Turbulent		diffused
3.73E-05	0.441523	5324.933297	Turbulent		diffused
1.41E-05	0.167497	1958.087475	Laminar		straight
8.94E-06	0.105836	1282.063125	Laminar		straight

Table 5: Alternate calculation of dynamic viscosity using data from (Reid et al., 1987) and some of the values that would come out if those values were used instead.

dynamic viscosity (other source) (mPa-s) Reid, Prausnitz, & Poling (1987)	dynamic viscosity (Pa-s)	implied Kinematic viscosity	implied Reynold's number
0.88990845	0.000889908	8.92749E-07	320.8985232
0.882133926	0.000882134	8.85044E-07	938.3172868
0.893834617	0.000893835	8.9664E-07	2543.23977
0.872559485	0.000872559	8.75557E-07	2273.145657
0.893834617	0.000893835	8.9664E-07	4033.03183
0.874461738	0.000874462	8.77441E-07	641.9449861
0.891868269	0.000891868	8.94691E-07	5545.287654
0.874461738	0.000874462	8.77441E-07	5218.118553
0.901765838	0.000901766	9.04502E-07	1920.329973
0.870663498	0.000870663	8.73678E-07	1256.210747

Table 6: table as source of the value for the alternative calculation of dynamic viscosity. T is the temperature of the fluid in Kelvin.

Liquid	Chemical formula	A (mPa · s)	B (K)	C (K ⁻¹)	D (K ⁻²)	Temp. range (K)
Water	H ₂ O	$1.856 \cdot 10^{-11}$	4209	0.04527	$-3.376 \cdot 10^{-5}$	273–643
Ethanol	C ₂ H ₆ O	0.00201	1614	0.00618	$-1.132 \cdot 10^{-5}$	168–516
Benzene	C ₆ H ₆	100.69	148.9	-0.02544	$2.222 \cdot 10^{-5}$	279–561
Cyclohexane	C ₆ H ₁₂	0.01230	1380	$-1.55 \cdot 10^{-3}$	$1.157 \cdot 10^{-6}$	280–553
Naphthalene	C ₁₀ H ₈	$3.465 \cdot 10^{-5}$	2517	0.01098	$-5.867 \cdot 10^{-6}$	354–748

IV. RESULTS AND DISCUSSION

Discussion and interpretation of results are technically sound and logically correct. Results must be verified with established values.

The predicted flow characterizations were manifested in the given Reynold's number regimes.

Turbulent flows were shown to manifest at the Reynold's number of above 4113, Laminar flows at the Reynold's number 1958 and below.

From the separation of the characterizations given different Reynold's numbers. It could be said that Reynold's number is useful in the characterization of flows.

The data sheet at table 4 summarizes the findings.

V. CONCLUSIONS

Turbulent flows were shown to manifest at the Reynold's number of above 4113, Laminar flows at the Reynold's number 1958 and below.

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VI. RECOMMENDATIONS

Recommend any practical way of improving the experiment.

A method of improving the experiment is by using some method to allow our intuitive notion of straight, wavy, or diffused flow to be expressed in the form of a mathematical formula other than Reynold's number.

Another way of improving the experiment is by finding out what would happen if the explanation of what would happen would hold up at extremely high Reynold's numbers.

VII. REFERENCE

Daugherty, R. L., Franzini, J., & Finnemore, J. E. (1989). *Fluid Mechanics with Engineering*

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Reid, R. C., Prausnitz, J. M., & Poling, B. E. (1987). *The properties of gases and liquids* (4th ed).

McGraw-Hill.

Streeter, V., & Wylie, B. (n.d.). *Fluid Mechanics, Metric Edition, 7th Edition*. McGraw Hill.